"LISTEN2DROOM": HELPING VISUALLY IMPAIRED PEOPLE NAVIGATE INDOOR ENVIRONMENTS USING AN ULTRASONIC SENSOR-BASED ORIENTATION AID

Seyedeh Maryam Fakhr Hosseini[1], Andreas Riener[2], Rahul Bose[1], and Myounghoon Jeon[1]

[1]Mind Music Machine Lab
Michigan Technological University
1400 Townsend Drive, Houghton, MI 49931
{Sfakhrho, rbose, mjeon}@mtu.edu

[2]Institute for Pervasive Computing
University of Linz
Altenberger Strasse 69, 4040 Linz/Austria
riener@pervasive.jku.at

ABSTRACT

People with visual impairments face considerable limitations with their mobility, but still there is little infrastructure in place to help them. In this study, we present a new wearable electronic travel aid (ETA), "Personal Radar", which assists blind people in navigating in indoor environments using an ultrasonic sensors. After briefly describing our initial system design, we report the improvements from the pilot study. Then, we introduce our experiment in progress. In the experiment, blind folded students and visually impaired people will navigate through a maze and an empty room based on auditory and vibrotactile feedback of the device. This system could serve as an effective research platform for obstacle detection, current location awareness, and direction suggestion for the blind.

1. INTRODUCTION

Despite researchers' steady efforts in assistive technology, blindness remains a main challenge in accessibility. One of the problems that blind or visually impaired people encounter is navigation. Navigation includes updating one's position and orientation while the individual is traveling an intended route, and in the event the person becomes lost, it also includes reorienting and reestablishing a route to the destination. [2]. In this process three factors play an important role, which provides users with sufficient information to analyze the current situation: (1) the user's *current location* in the environment, (2) the presence of potential *obstacles*, and (3) the *direction* in which the user is traveling [3]. Guiding people requires providing them contextual information, which includes not only obstacle detection, but also optimal routing [2].

Even though various mobility devices and navigation systems are already out there [see 5, 6 for review], most systems for visually impaired people, such as GPS, mini guide, mobility aid, k sonar, guide dogs are helpful for outdoor navigation, or work only in restricted situations or environments. There are only a few studies regarding indoor navigation to improve blind people's independence [e.g., 1, 2]. Also, infrared technique is vulnerable to interference from sunlight and laser technology is still expensive [1]. To tackle these problems, we have launched the "Listen2dRoom" project [4]. In the first phase, we have identified user needs and critical variables with blind participants and assistive technology specialists, designed and evaluated a prototype system to convey information about an unfamiliar room layout. In the present phase, we expand the research scope from a room to further indoor environments by including an ultrasonic sensor-based ETA. Auditory and tactile channels are most commonly used compensatory senses that help people to get information about the distance, obstacles, orientation, etc. [7-9]. Given that multimodality is generally better than unimodality, we integrate auditory and tactile senses as feedback channels. To this end, we have developed a self-contained indoor ETA, "Personal Radar" [3], for obstacle detection, current location awareness, and direction suggestion.

2. SYSTEM DESIGN

The Personal Radar consists of three main components: ultrasonic sensors, tactile actuators, and microcontroller (Figure 1). These devices serve as a self-contained personal sensing system for boundary detection and collision avoidance. The ultrasonic sensor system with five distance sensors is used for time-to-flight measurements for estimating the distance to an object. The vibrotactile feedback unit with 8 tactors provides feedback in primarily four different forms (Figure 2): (1) There is no tactile output for obstacles 2m away from sensors, (2) slow pulsing for indicating that an object will be reached in sometime, (3) fast pulsing for indicating the first stage of warning implying that the obstacle will be reached in "short" time of walking, and (4) continuous vibrotactile signal to indicate that the object is very close and the user should stop walking in that direction. The core component of the main controlling unit is an Arduino ATmega2560 based microcontroller board integrated into a plastic housing mounted on the sensor belt. Additionally, we have a buzzer for auditory feedback which works in the same principle as vibrotractile feedback (Figure 2). Using this information, the system determines users' trajectory, locates in that path, and provides auditory and tactile feedback about their navigation.

3. Pilot Study

For concept validation, we conducted a pilot study. Twelve undergraduate and graduate students (mean age = 28, female =8) navigated one of the three different conditions: an empty room and a maze with manipulated feedback type (no feedback, auditory, tactile, and auditory + tactile feedback).

(a) (b)

Figure 1. (a) participant wearing two belts: the lower one includes ultrasonic sensors and the upper one includes vibrotactile sensors. (b) ultrasonic sensor belt with five ultrasonic range finders and 180 degree angle of beam.

All participants were blindfolded. This pilot study evaluated whether the use of the ultrasonic belt has an impact on indoor navigation for visually impaired people (temporarily or permanently) to find right directions and improve their moving time. The result of the pilot study gave us valuable information regarding how we can improve our personal radar system and experiment: First, provided that no collision occurred, it would be better to match the pulse of the individual actuator to the direction of the obstacle; when an obstacle is detected in a certain direction, only those actuator(s) would vibrate. Second, the hands of participants sometimes interfered with the ultrasonic sensors due to the placement of the sensors around the waist. This can be resolved by concentrating the sensors on the frontal part of the body. Finally, participants found it difficult to get an estimate of distances below 1m because it was hard for them to perceive a noticeable difference in frequency and pulse from both auditory and tactile feedback when they were approaching less than 1m to the obstacle.

4. EXPERIMENT IN PROGRESS

Forty-eight blindfolded college students will navigate two unfamiliar places with different feedback types. The study is a split-plot design with feedback type (no feedback, auditory, tactile, and auditory + tactile feedback as a between-subjects design) and navigation space type (an empty room and a maze as a within-subjects design). First, the participant will wear the instrument belts around the participant’s waist. Then, an experimenter will bring the participant into the starting position, either in an empty room or a room with a maze. For the no feedback group, participants will use their hands to navigate the place. Then, the experimenter will initiate the device to start collecting data about their trajectory. Then, the participant will navigate the room to the other side (or to the end of the maze). Once the participant reaches the destination, the experimenter will stop collecting data. The system will record the distance travelled and time taken, with respective plots. In addition, we will obtain the number of collision, user trajectory, participants’ subjective assessment including workload (NASA-TLX). Results are expected to show that the use of multimodal feedback will be more efficient in terms of navigation time and user trajectory than unimodal feedback (e.g., current data show this trend: 121 sec for empty room and 171 sec for maze with auditory feedback, $N = 5$ vs. 42 sec for empty room and 115 sec for maze with auditory and tactile, $N = 5$). The subjective assessment is also expected to favor multimodal over unimodal display (e.g., current TLX data show this trend: 51/100 with auditory feedback, $N = 5$ vs. 40/100 with auditory and tactile, $N = 5$). It is also of interest whether our system can outperform no feedback condition in terms of navigation time because people might need more mental resources to process feedback.

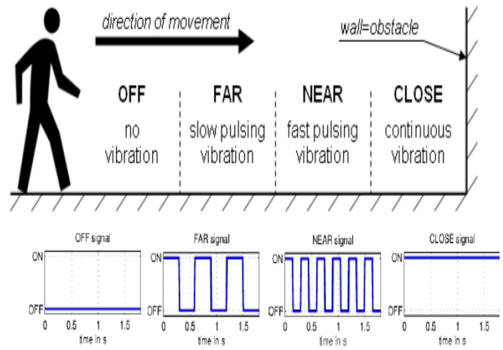

Figure 2. Vibrotactile and auditory feedback displays.

5. CONCLUSION AND FUTURE WORK

We have developed an ultrasonic sensor-based indoor ETA system, which also has multimodal feedback. Our preliminary data have shown us promising results in terms of feasibility and effectiveness of the system. After running the on-going experiment, we plan to recruit our target populations (i.e., visually impaired and blind people) and conduct the next experiment. Based on our needs analysis [4], we also consider to combine speech and non-speech sounds for auditory displays (e.g., obstacle: non-speech sounds, direction: speech sounds) in addition to implementation of 3D sound for better spatial resolution to direct users where to expect an obstacle to avoid.

6. REFERENCES

[1] L. A. Guerrero, F. Vasquez, S. F. Ochoa, “An indoor navigation system for the visually impaired,” *Sensors*, vol. 12, no. 6, pp. 8236-8258, 2012.

[2] L. Ran, S. Helal, S. Moore, “Drishti: An integrated indoor/outdoor blind navigation system and service,” in Proc. of the 2nd IEEE Annual Conf. on Pervasive Computing and Communications, 2004, pp. 23-30.

[3] A. Riener, H. Hartl, “Personal Radar: A self-governed support system to enhance environmental perception,” in Proc. of the 26th Annual BCS Interaction Specialist Group Conf. on People and Computers, 2012, pp. 147-156.

[4] M. Jeon, Nazneen, O. Akanser, A. Ayala-Acevedo, B. N. Walker, “Listen2dRoom: Helping blind individuals understand room layouts,” in Extended Abstracts Proc. of the SIGCHI Conf. on Human Factors in Computing Systems, 2012.

[5] R. Velázquez, “Wearable assistive devices for the blind,” in A. Lay-Ekuakille & S.C. Mukhopadhyay (Eds.), Wearable and autonomous biomedical devices and systems for smart environment: Issues and characterization, LNEE 75, Springer, 2010, pp. 331-349.

[6] W. F. Leicester, "Mobility devices", in: Foundations of orientation and mobility (ed.), R.L. Welsh & B.B. Blasch, American Foundation for the Blind. pp. 357-412, 1980.

[7] K. Tsukada, M. Yasumrua, “ActiveBelt: belt-type wearable tactile display for directional navigation,” In: Proc. of UbiComp2004, Springer LNCS3205, 2004, pp 384-399.

[8] S. Nagel, C. Carl, T. Kringe, R. Märtin, P. König, “Beyond sensory substitution-learning the sixth sense,” Journal of Neural Engineering, vol. 2, pp R13-R26, 2005.

[9] R. Farcy, Y. Bellik, "Locomotion assistance for the blind," Applied optics, universal access and assistive technology, 2002.